1990MNRAS.247P..21F

Mon. Not. R. astr. Soc. (1990) **247**, *Short Communication*, 21P–25P

Large-scale structure in the Universe: plots from the updated *Catalogue of Radial Velocities of Galaxies* and the *Southern Redshift Catalogue*

A. P. Fairall,[1] G. G. C. Palumbo,[2] G. Vettolani,[3] G. Kauffmann,[1] A. Jones[1] and G. Baiesi-Pillastrini[3]

[1] *Department of Astronomy, University of Cape Town, Rondebosch, 7700 South Africa*
[2] *Dipartimento di Radioastronomia, Università di Bologna e Istituto Technologie Studio della Radiazioni Extraterrestri CNR, Via Zambonini 23, 40126 Bologna, Italy*
[3] *Istituto di Radioastronomia CNR, Via Irnerio 46, 40126 Bologna, Italy*

Accepted 1990 October 1. Received 1990 September 26; in original form 1990 July 13

SUMMARY

Available redshifts, even though not statistically controlled, can be successfully used to map large-scale structures. We have merged the almost-complete *Catalogue of Radial Velocities of Galaxies* and the *Southern Redshift Catalogue* to form a large database of available redshifts. Sets of plots, covering the entire sky to a heliocentric velocity of 10 000 km s^{-1}, are presented. A long wall having two right-angled bends has been found. Evidence of double-wall structures is also apparent. One of the circular voids in the plots has a clump of Markarian galaxies in its centre.

1 INTRODUCTION

The reception accorded the *Catalogue of Radial Velocities of Galaxies* (Palumbo, Tanzella-Nitti & Vettolani 1983) has prompted the preparation of an updated version (by Palumbo *et al.*, in preparation) that will include references to early 1988, and is now virtually complete (hereafter referred to as CRVG). The new version contains nearly 30 000 radial velocity measurements. In parallel to this effort, one of us (APF) has, since 1981, maintained a southern redshift catalogue (hereafter SRC). The last published version was by Fairall & Jones (1988) but it is continually being updated. It currently incorporates over 10 500 velocity measurements, giving redshifts for 8250 southern galaxies.

This paper presents redshift plots – slices in Right Ascension (RA) and Declination (Dec.) – made from these catalogues. It therefore uses a large number of 'available' redshifts, rather than a statistically controlled sample of redshifts such as the well-known magnitude-limited CfA 'slices' (Geller & Huchra 1989). While statistically controlled samples are very necessary for quantitative analysis, our approach is nevertheless useful for the mapping of large-scale structures. For example, Fig. 1 shows exactly the same large-scale structures as does the original 'Slice of the Uni-

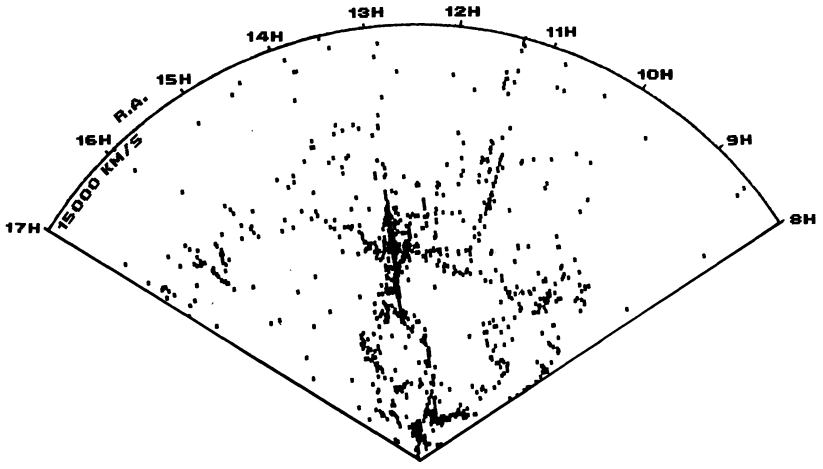

Figure 1. Distribution of galaxies in redshift space for Dec. 27°.5 to 37°.5. The large-scale structures (i.e. the 'man' figure and its extensions) are the same as those in the well-known CfA slice.

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verse' (de Lapparent, Geller & Huchra 1986), yet it does not contain CfA slice redshifts. Similar examples can be given in the southern skies (see the discussion by Fairall *et al.* 1990). Controlled 'slices' cover only a part of the sky; the advantage of using catalogued redshifts is that they cover the entire sky.

2 DATA AND GENERAL PLOTS

Four separate files (CRVG to 1980, 1981–1986, 1987–early 1988, and the SRC) were merged to form a single database. Various filters were applied to combine multiple entries

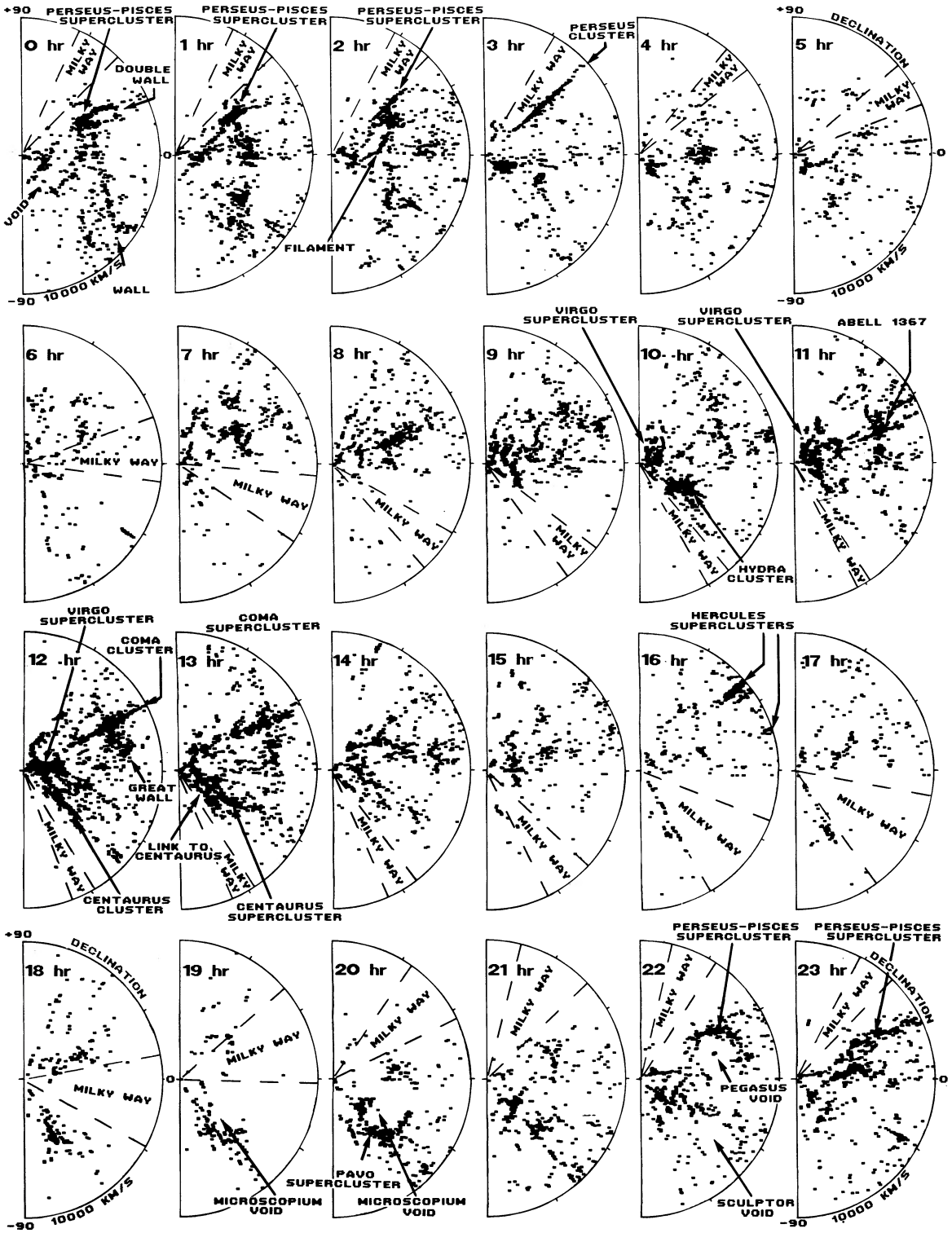

Figure 2. Slices in Right Ascension to a heliocentric velocity of 10 000 km s^{-1}, covering the entire sky. The first covers RA range $00^h00^m00^s$ to $00^h59^m59^s$, the next $01^h00^m00^s$ to $01^h59^m59^s$, and so on. Prominent features are labelled.

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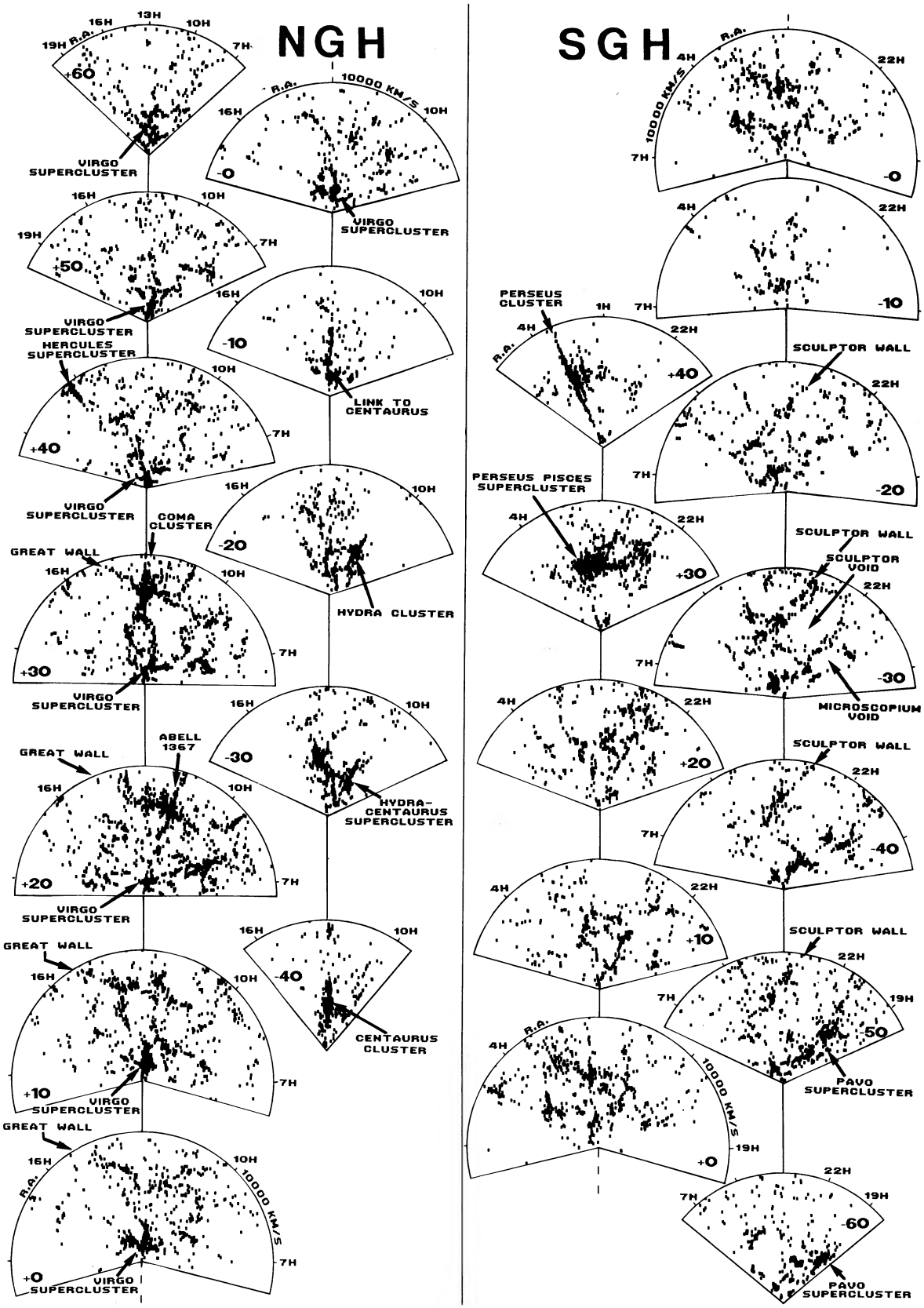

Figure 3. Slices in Declination, to a heliocentric velocity of 10 000 km s^{-1}, for the Northern Galactic Hemisphere (NGH) and Southern Galactic Hemisphere (SGH). A northern slice marked +30 covers the Dec. range 27°.5 to 37°.5, a southern equivalent −27°.5 to −37°.5; thus there is overlap between the slices marked +0 and −0.

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which were related to the same galaxy (since different investigators publish different names, give slightly different coordinates, and obtain slightly different redshifts). The final data file contains approximately 22 000 galaxies. This database has been used for all plots accompanying this article. A full set of plots in RA and Dec. is presented in Figs 2 and 3. Fig. 2 supersedes an earlier version of such plots (Fairall *et al.* 1985).

Concentrations, superposed on a labyrinth of straight and curvilinear structures, are mapped to 10 000 km s^{-1}. Many of the individual structures are already well known. For example, the Perseus–Pisces region has long been studied by Giovanelli & Haynes (e.g. Giovanelli 1990), while the region adjacent to the Coma cluster is well studied by the CfA surveys. The purpose of this paper is to make a visual presentation and not to carry out any major analysis of the structures, although a few new features deserve some discussion.

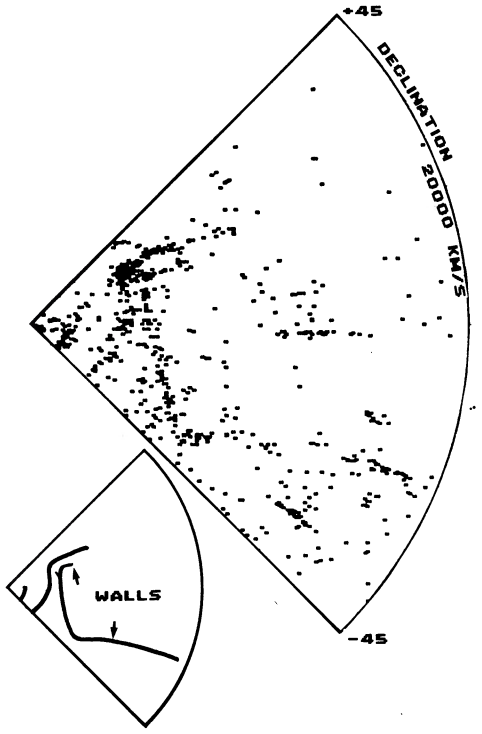

Figure 4. Wall-like features are seen in cross-section in this RA slice $00^h00^m00^s$ to $00^h59^m59^s$. One of them shows two sharp bends – the arrows show the limits of a percolation analysis, described in the text.

3 THE CETUS WALL

Fig. 4 reveals evidence of a remarkable structure which we shall refer to as the Cetus Wall. Not only is it very long, with an overall velocity range in excess of 20 000 km s^{-1}, but it appears to make two sharp right-angled bends. One of these is adjacent to the Perseus–Pisces supercluster, at which point it runs parallel to a similar wall, thus producing a double-wall structure. It should be noted that much of this wall was identified in the early plots (Fairall *et al.* 1985), where even the double structure can be discerned. In the south, the wall runs up against the Sculptor supercluster (da Costa *et al.* 1988; Fairall & Jones 1988) – now better designated as the Sculptor Wall.

The plot in Fig. 4 shows a projection of what is really a three-dimensional distribution. It is therefore not clear from the plot whether the Cetus Wall is truly a two-dimensional wall rather than a one-dimensional filament. Moreover, it is not clear whether the right-angled bends are real or artefacts resulting from the projection of the data. If the bends are real, then they could be critical tests for any theoretical model.

We have investigated the reality of the bends, using a percolation analysis routine operating in the three-dimensional redshift space in the vicinity of the Cetus Wall. In order to cope with the lack of statistical control in the data, the percolation sphere's volume was varied inversely with the general selection function of the database. The latter is shown in fig. 3 of Kauffmann & Fairall (1990) (where this same database is used for a different purpose) and is found to depend on declination and radial velocity. We find that, with a percolation radius of 475 km s^{-1} (at the centre of the wall), the entire structure between the marker arrows in Fig. 4 is connected. The right-angled bends close readily; in the south a percolation radius of only 375 km s^{-1} is needed. Thus we conclude the bends are real features in one continuous structure.

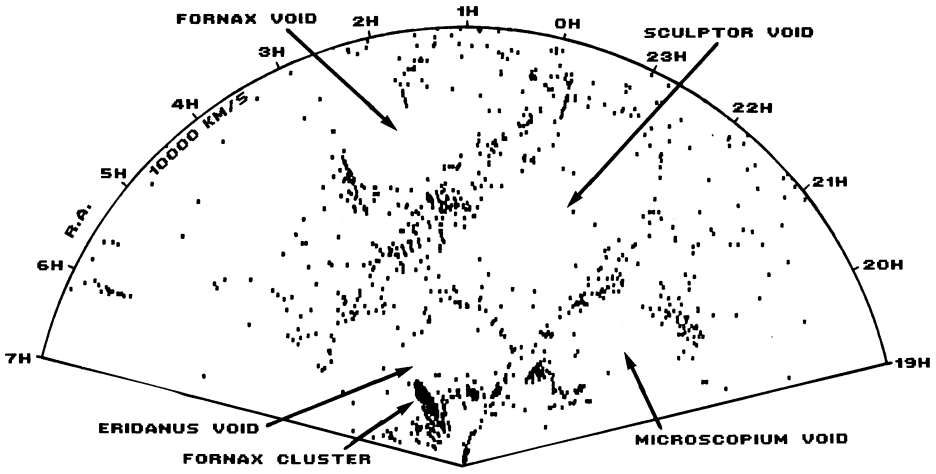

Figure 5. Distribution of galaxies in the Declination range $-22°.5$ to $-42°.5$ in the Southern Galactic Hemisphere.

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A separate investigation showed that the wall does indeed have a limited two-dimensional extent, though its plane is not quite perpendicular to the plane of Fig. 4. The plane is also not constant along the length of the wall, but appears to twist slightly, causing the wall to take on an almost ribbon-like characteristic. Since it generally runs perpendicular to the line-of-sight, the wall cannot be distinguished on sky plots – we have checked the plots of UGC, ESO and MCG galaxies (Sharp 1986) and *IRAS* galaxies (Meurs & Harmon 1988). This is also the case for the Great Wall through the Coma supercluster.

4 SOME WELL-DEFINED VOIDS

In the RA slice for 0^h (both in Fig. 2 and Fig. 4) a void at radial velocity around 3000 km s^{-1} runs from northern to southern declinations. The void apparent in front of the Perseus–Pisces supercluster (Giovanelli 1990) is the same as that found independently in the south (Fairall 1984; da Costa *et al.* 1988).

RA slices 19^h and 20^h (Fig. 2) show the Microscopium Void (first identified by Fairall 1984) very distinctly (except for a lack of redshift data centred on Dec. $-15°$).

RA slice 22^h (Fig. 2) shows what we term the Pegasus void. It has a circular profile, but there is an isolated clump of galaxies at its centre. This clump includes the emission-line galaxies Mkn 305, 306 and 307. A similar situation occurs in the Bootes void (Chincarini & Vettolani 1987).

A number of well-defined voids show up in the Dec. slices around $-30°$ in the southern galactic hemisphere, as shown in Fig. 5. While the data shown are 'available' redshifts, this area is also under investigation using 'controlled' redshifts by da Costa *et al.* (1989). In this collaboration (involving APF), even more redshifts have been obtained than are represented here. We hope their quantitative analysis may complement the visual impressions of the diagram.

ACKNOWLEDGMENTS

APF thanks the Italian CNR for funding which made this collaboration possible. We thank Peter Martinez for help in reading tapes into the UCT mainframe computer, and the referee for useful suggestions.

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